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ABSTRACT

Bolted cores made of coated silicon steel sheets constitute a vital part of heavy electrical equipment for transformers, motors and turbogenerators. Bolted laminates are eminently suitable for facilitating smooth magnetic flux paths, but, unfortunately, they are unable to suppress interlaminate shearing caused by flexural vibration generating noise levels often exceeding 100 dB during operation. The resulting din and cacophony in the surrounding has become a major environmental concern. This thesis makes an attempt to develop theoretical, experimental and numerical models for evolving an *effective* stiffness approach enhancing the design and analysis underlying nonlinear flexure of bolted laminates.

While large machine cores contain thousands of thin sheets bolted together along with end plates, this thesis reports the results obtained on two different assemblies. Two 375 mm long 60 mm wide and 10 mm thick plates assembled with 3, 4 or 5 bolts constitute the first configuration. The second one which is much more realistic comprises 80 coated 270 micron silicon steel sheets with end plates of 2 or 4 mm thickness held together by 3 or 5 bolts. Static 3 point bend tests on these bolted assemblies are followed by instrumented impact tests. Static bending tests highlight the role of frictional nonlinearity inducing a drop in the stiffness due to sliding between the plates. An experimentally determined *effective modulus* in the initial linear range is utilized for static and dynamic finite element simulations. Nonlinear response of bolted plates is simulated using contact elements in between the sliding plates, plates and the bolts heads. Since the first fundamental mode of vibration dominates the tribomechanical vibration induced noise, the primary focus is on the fundamental frequency in bending.

There is generally a good overall agreement in all the results obtained through theory, experiment and FE simulation. Experiments, however, unveil quite complex nonlinear effects induced by friction and plasticity outside the scope of this thesis. However, the low amplitude response of bolted laminates which is reasonably well captured in this thesis represents the starting point for initiating a more elaborate effort for addressing large amplitude nonlinear flexure in bolted laminates. These findings shed light on estimating and controlling noise and vibration levels in heavy electric machines.